Development of Mirror Segments for Constellation-X

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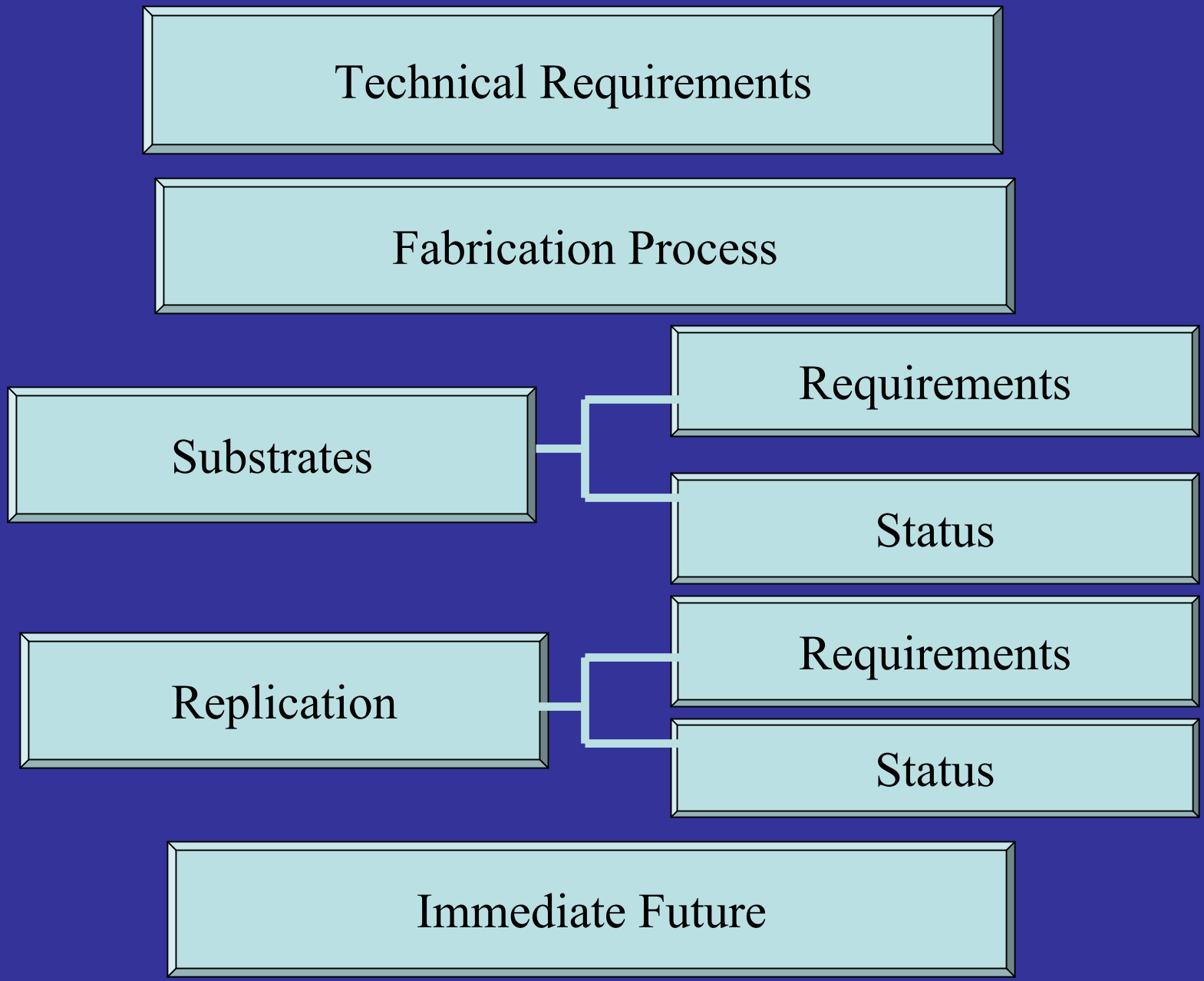
Technical Requirements
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Requirements
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Specifications of Mirror Segments

1. Mass: Areal density less than 1.5 kg m^2
   - Glass thickness < 600 μm
   - Current Baseline: 400 μm
2. Dimension:
   - 60^o segments for inner shells
   - 30^o segments for outer shells
   - Axial Height: ≥ 20cm
   - Smallest mirror segment: 21cm×20cm
   - Largest mirror segment: 42cm×20cm
3. Figure (spatial frequency 0.3 to 200mm):
   - Axial slope RMS error < 2"
   - Circularity error < 10μm
   - Average radius error < 100μm
   - Average slope (cone angle) error < 30"
4. Microroughness (spatial frequency 1 to 300 microns):
   - 6Å RMS (1-300μm)

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Fabrication Process

- **Substrate Fabrication**
  - **Material:** Schott D263 glass sheets
  - **Forming Mandrel:** conical in shape, relatively coarse in figure, and inexpensive
  - **Forming Process:** heating cycle and glass sheets conform to the shape of the mandrel under gravity
- **Replication**
  - **Replication Mandrel:** Precision figured and polished ZeroDur Wolter-I
  - **Replication Mandrel Coating:** Au
  - **Epoxy Application on Substrate:** 40μm for now and 10μm in future
  - **Mating:** Epoxy-coated Substrate and Au-Coated Replication Mandrel are placed together in vacuum to avoid air pockets

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Specifications of Substrates

- **Overall Figure:** conical in shape, forming mandrel being the conical approximation of the corresponding Wolter-I geometry
- **Tolerances:**
  - Cone angle: ±20”
  - Axial Straightness: ±2μm
  - Roughness: ~20Å RMS
  - Roundness: ±5μm

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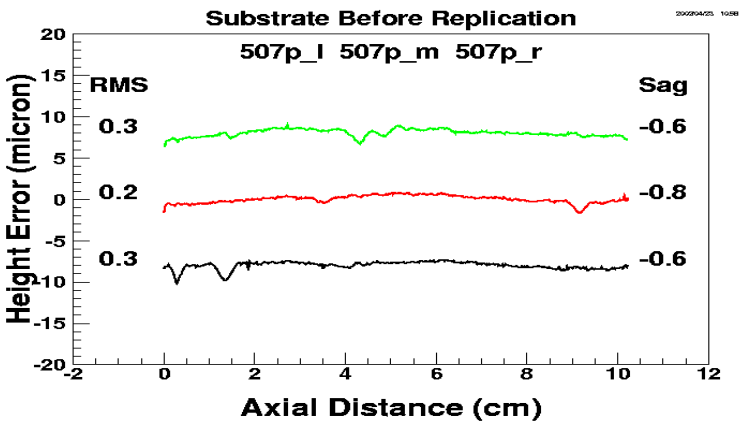
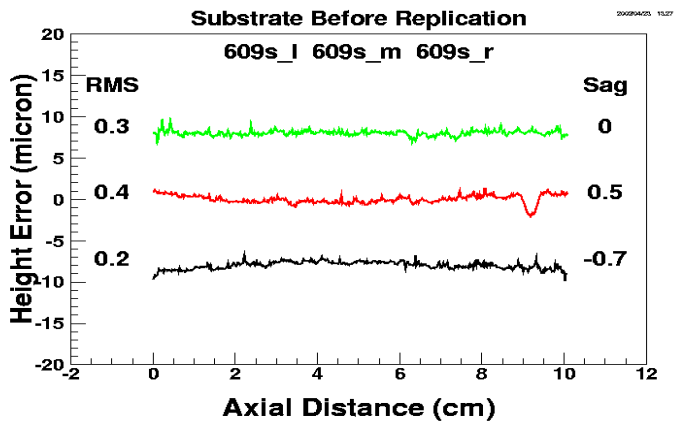
Quality of Formed Substrates





- Excellent substrates are being formed. They deviate from the forming mandrel by no more than 1.5μm
- They are essentially perfect for use with replication with an epoxy thickness of ~10μm

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Requirements on Replication Process

- It has to bridge the gap between the quality of the substrate and the final requirements on the mirror segment
- The epoxy layer has to be **thick** enough to smooth out the irregularities of the substrate **and** to create the necessary Wolter-I curvature
- The epoxy layer also has to be **thin** enough to reduce temperature sensitivity of the finished replica to an acceptable level.
- Present Baseline Epoxy Thickness: 10 to 20μm

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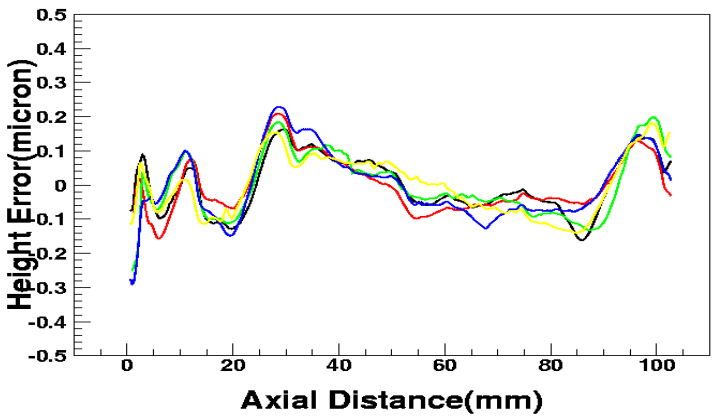
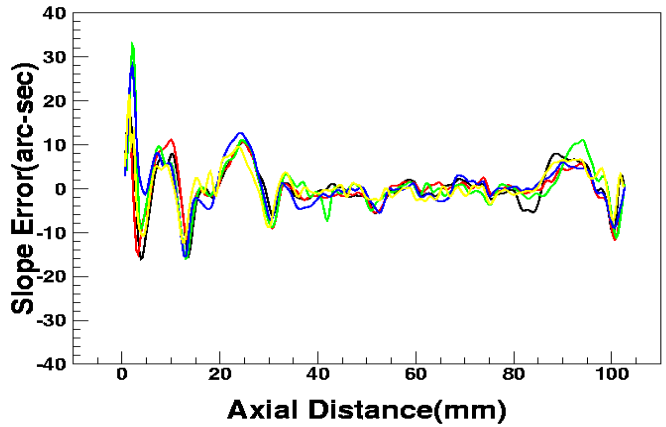
Quality of Replication





- Figure on left: Height (or relative radius) errors of a replica
- Figure on right: Slope errors of the same replica
- This is one of the best replicas that have been done so far. It demonstrates the potential of the epoxy replication technology. More work is needed to achieve consistency and increase yield.

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Immediate Plan

- Form segments that are 20cm in axial length and 50cm in diameter using forming mandrels that just arrived last week
- Replicate the segments off a 50-cm diameter mandrel fabricated by Zeiss
- Demonstrate that mirror segments meet requirements by end of 2002

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